AS Unit BY2: Biodiversity and Physiology of Body Systems

Name:	Date:

Topic 2.1 All Organisms are related through their Evolutionary History

2.1 From your syllabus

(a) the classification of organisms into groups based on their evolutionary relationships and that classification places organisms into discrete and hierarchical groups with other closely related species

(b) the need for classification and its tentative nature

(c) the three domain classification system as compared with the five Kingdom classification system

(d) the characteristic features of Kingdoms: Prokaryotae, Protoctista, Plantae, Fungi, Animalia

(e) the use of physical features and biochemical methods to assess the relatedness of organisms, including that DNA 'genetic fingerprinting' and enzyme studies show relatedness without the problem of morphological convergence

(f) the concept of species

(g) the use of the binomial system in naming organisms

(h) biodiversity as the number and variety of organisms found within a specified geographic region

(i) biodiversity varying spatially and over time and affected by many factors

(j) biodiversity can be assessed in a habitat e.g. Simpson's Diversity Index

(k) biodiversity can be assessed within a species at a genetic level by looking at the variety of alleles in the gene pool of a population, i.e. the proportion of polymorphic loci across the genome

(l) biodiversity can be assessed at a molecular level using DNA fingerprinting and sequencing

(m) biodiversity has been generated through natural selection

(n) the different types of adaptations of organisms to their environment including anatomical, physiological and behavioural adaptations

SPECIFIED PRACTICAL WORK

- Investigation into biodiversity in a habitat

A very general definition of biodiversity is "the **variety** of **species** on this earth". In this section we will address a number of issues, for example:

- What is a species and how can the enormous diversity on this planet be arranged into manageable groups for study purposes (**classification**)?
- What role has evolution played in bringing about the existence of the biodiversity of life forms found on out planet.

This topic covers biodiversity and classification. The variety of living organisms that exists today has evolved as a result of natural selection. Modern techniques have allowed more accurate classification to confirm evolutionary relationships.

End of topic check list for 2.1 Organisms are related through their Evolutionary History

Tick as appropriate:
RED : I do not know about this
AMBER: I have heard about this but have not learned this yet. I am unsure on this.
GREEN: I have heard about this and I have learned this. I am confident about this.

Topic	RED	AMBER	GREEN
1. Biodiversity of a geographical area is a factor of the number and variety of different organisms.			
2. A species is a group of organisms that can interbreed under natural conditions and produce fertile offspring.			
3. The number of species per square km increases as one moves from the poles to the tropics. Tropical rain forest and coral reefs are the most diverse habitats on the planet.			
4. The fossil record shows that most species are now extinct.			
5. Evolutionary history shows that biodiversity has gone through several bottlenecks called mass extinctions followed by radiations of new species.			
6. Biodiversity has been generated through the process of natural selection.			
7. The biodiversity of a habitat can be assessed using the Simpson's Diversity Index.			
8. The biodiversity within a species can be assessed at a genetic level by looking at the variety of alleles in the gene pool of a population i.e. the proportion of polymorphic loci across the genome.			
9. The classification of organisms is based on their evolutionary history.			
10. Classification is needed so that some order is placed on the natural world and it can be studied. Classifying an organism is always tenuous in nature as its classification is based on the information that is known, in the future new information may become apparent that alters its classification.			
11. One classification concept is that of a simple phylogenetic tree.			
12. Be able to compare classification using the 3-domain system or the five-kingdom system.			
13. All organisms can be placed into a hierarchical system of classification that includes – kingdom, phylum, class, order, family, genus and species.			
14. Organisms are more closely related with progression from Kingdom to species. Taxonomy is dynamic and there are differences of opinion about whether morphology or genetics are more central as a basis for the classification of organisms.			

15. Understand the basic characteristics of the five kingdoms: Prokaryotae (unicellular, microscopic, no internal membrane based organelles, no nuclear membrane, cell wall not cellulose) Protoctista (eukaryotes, mainly single celled organisms, no tissue differentiation) Plantae (multicellular eukaryotes, photosynthetic, cellulose cell walls) Fungi (heterotrophic eukaryotes, rigid cell walls of chitin, reproduce by spores) Animalia (heterotrophic, multicellular eukaryotes, no cell wall, nervous coordination)			
16. The animal kingdom is split into major phyla and several smaller ones. (only names of those specified in 16 are needed)			
17. Each phylum includes animals based on a shared basic blueprint.			
18. A genus is a group of closely related species; the binomial system of naming organisms includes both a genus and a species name.			
19. The basic features of the following phyla: **Annelids** 8000 named species for e.g. leeches, earthworms and lugworms. Segmented worms with a closed circulatory system, hydrostatic skeleton; specialised segments responsible for different functions, thin permeable skins used for gas exchange. **Arthropods** 1 million named species for e.g. <u>insects</u> e.g. locust, <u>crustaceans</u> e.g. lobster, <u>arachnids</u> e.g. spider, <u>myriapods</u> e.g. centipedes. Characterised by having joined legs, an exoskeleton, and a fluid filled cavity. Advantages of an exoskeleton. Insects are the most successful group of animals on the planet. Insects are characterised by 2 pairs of wings and 6 legs – in some these have been lost e.g. flea, ant and lice. **Chordates** 60,000 named species. Known as 'vertebrates' possessing a vertebral column or backbone (do not need to use the term notochord), well developed CNS enclosed within the cranium. Phylum subdivided into: <u>fish</u> (scales, gills, live in water), <u>amphibian</u> (soft moist skin, simple lungs, live on land but water needed for lifecyle), <u>reptiles</u> (dry scaly skin, lungs, land based, lay eggs with leathery shells), <u>birds</u> (endothermic, lungs, feathers, forelimbs modified for flight, eggs with hard shells), <u>mammals</u> (endothermic, lungs, hair, double circulation, internal gestation, mammary glands and sweat glands			
20. Closely related species are recognised by their similar morphology, e.g. the homology of the pentadactyl limb in vertebrate. Analogous structures such as the wings of a bird and insect are not an indication of relatedness.			
21. Biochemical methods measure the proportion of genes or proteins shared between species to estimate relatedness. Proteins are usually displayed as bands on an electrophoresis gel. Biochemical methods can reduce the mistakes made in classification due to convergent evolution.			
22. Organisms show a range of adaptations to their environment including anatomical, physiological and behavioural.			

2.1 Biodiversity and Evolution – Page 1

A. Biodiversity and Evolution

		Completed
1.	• Watch 'State of the Planet – Is there a crisis?' • Complete the question sheet, which will provide notes about biodiversity.	
2.	• Read 'Why We Need Biodiversity' and then look at your homework task for this week.	
3.	• Read through the rest of the notes	
4.	• Use the video clips to add extra detail and depth to your notes and understanding	
5.	• Read about ecosystems stability on page 16 • Understand the use of the Simpson's Diversity Index • Complete the questions on page 17	
6.	• Read about the genetic diversity within a single species p19 and appreciate its significance in determining how resilient the species is to extinction.	

STATE OF THE PLANET Part I – Is there a crisis?

Summarise the programme using the following questions for guidance:

Q1. Why is there such uncertainty about the number of species in the world?

Q2. What techniques can be used to estimate biodiversity?

Q3. Name a species which has been rescued from the brink of extinction.

Q4. Why are the 'little things' the most important?

Q5. Which areas of the world are primarily understudied?

Q6. Define the terms LOCAL EXTINCTION and MASS EXTINCTION.

Q7. What is a KEYSTONE SPECIES? Give an example.

Q8. Why is it important to conserve biodiversity?

Bio Factsheet

www.curriculum-press.co.uk Number 224

Why we need biodiversity: Medicine

All organisms contain chemicals that help to protect them against disease or attack by other species. For example, a huge number of completely separate species contain similar proteins that help to protect them against infection by bacteria and fungi. Prey species such as some frogs and toads produce toxic alkaloids in their skin to prevent them from being eaten. Predators such as cone snails, spiders, snakes and scorpions produce toxic proteins that instantly paralyse their prey.

We can think of this as Nature acting as a chemist. These chemicals were not made to order when life began 3.5 billion years ago – they have evolved over that time. Chemicals that did not offer any advantage to an organism didn't survive. So we can think of Nature as having conducted an enormous clinical trial – one lasting 3.5 billion years!

Humans have benefited from this already. In the US, more than 50% of the most prescribed medicines come directly, or indirectly, from natural sources.

Direct source: We have identified a useful substance in a microbe, plant or animal, extracted it, learned how to synthesis it, and used it

Indirect source: Chemists have used the molecular structure of a useful substance to make new, slightly different substances i.e. we have used Nature's substances as a starting point.

So what's the problem? Nature is a gigantic Chemist shop and we are exploiting it and using it to make new, useful medicines aren't we?

The problem:

- A large number of useful substances have already been found
- But we have only analysed less than 1% of plants for their pharmacological activity and a vanishingly small proportion of animals and microbes
- We have only discovered a small fraction of the species that actually exist on the planet (a new species is discovered every 15 minutes)
- We are driving species to extinction somewhere between 100 - 1000 times faster than the natural rate

" The library of life is burning and we do not even know the titles of the books"

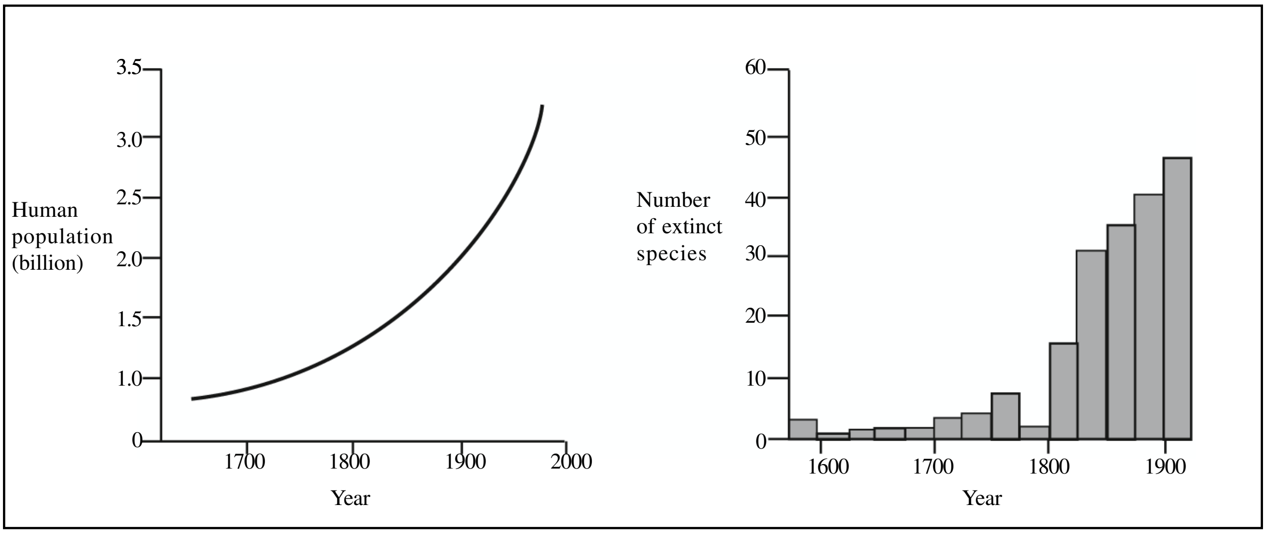
Dr G H Brundtland
Former Director-General of the World Health Organisation and former Prime Minister of Norway

So far, scientists have identified about 1.75 million different species of plant and animal. This doesn't include bacteria - we really haven't got a clue how many species of those there are!
`
The IUCN estimate that there are another 3 to 38 million species of plant and animal that have yet to be discovered. 15,000 new species are discovered every year (about one every 30 minutes!). There are many more species we don't know anything about than those we do!

Of the 1.75 million species on planet Earth, just one poses a huge threat to the millions of others – humans (Fig.1)

Homework! Choose one of the useful organisms on p2&3 and produce a more detailed report on its usefulness to medicine

Fig 1. Human population vs species exiction: linked?



There are, of course, many reasons why biodiversity should be maintained but as Table 1 shows, Nature represents a fantastic potential source of medicines and treatments.

Homework:

Choose one of the following (or a species of your own choice)

Bark of Cinchona tree / Sweet wormwood plant / Leaves of Pilocarpus jaborandi / Rosy Periwinkle / Bark of willow trees / *Calophyllum lanigerum* / Opium poppy / Purple Sea Urchin / Armadillo / *Hirudo medicinalis* / Canine hookworm / Penicillium notatum / *Amycolatopsis orientalis* / African clawed frog.

In pairs you are going to research a species and its significance to medicine, you will present this to your peers in the form of a **2 MINUTE** oral presentation **and** an A4 poster.

Criteria	**3**	**2**	**1**
Organism is introduced, where it is found etc.	3	2	1
Useful substance that organism produces is clearly given	3	2	1
How this substance was discovered is explained	3	2	1
Use of the substance is given	3	2	1
Explanation of how the substance works is given	3	2	1
Talk is easy to follow	3	2	1
The talk is shared evenly between the students	3	2	1
Visual aids have been used appropriately (they help give clarity and interest to the talk NOT as a verbal prop!!)	3	2	1
Good eye contact is made with the audience	3	2	1
Clear audible voice	3	2	1
Animated and not monotone	3	2	1
Poster is presented with all of the above	12	8	4
Total			
Grand Total	/**45**		
Percentage	%		

Biodiversity

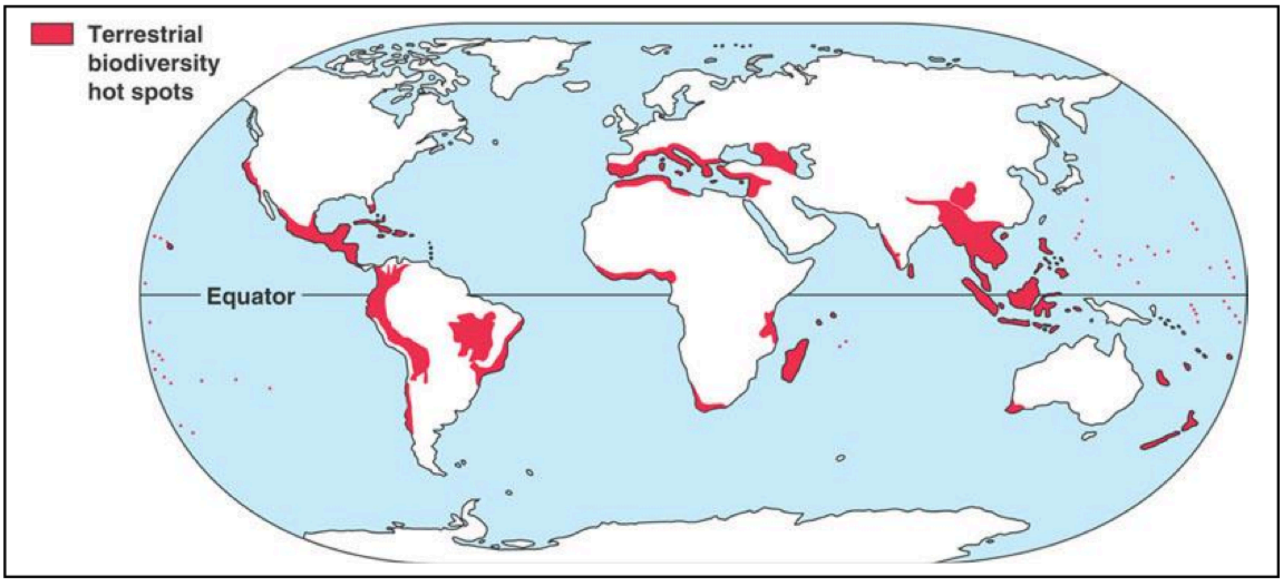
Biodiversity = a measure of the number of species on the planet

i.e. all living things: plants, animals, fungi, protoctists and prokaryotae

Biodiversity varies spatially and over time (temporally)

The number of species /km^2 increases as one moves from the poles to the tropics

Tropical rainforest and coral reefs are the most diverse habitats



Look at the first few pages of the PowerPoint and give some of the reasons why tropical rain forests are sources of so much biodiversity:

Biodiversity has been generated through natural selection and adaptation over millions of years.

Species = a group of organisms that can interbreed under natural conditions and produce fertile offspring.

Extension – Problems in defining a species
Although the definition given above may seem perfectly clear, it is difficult to apply to many situations. For example, two similar organisms may live in very different parts of the world, they obviously do not interbreed, because they never come into contact with one another. But would they interbreed if they could?
Other organisms may never breed sexually at all, and so never interbreed even with members of their own species. Some plants such as wild garlic do this. How do you tell if two types of wild garlic belong to different species or are just varieties of the same species? There are many plants that only reproduce asexually. The classification of prokaryotes runs into similar problems. In these cases, decisions have to be made solely on similarities in morphology and physiology, which not surprisingly leads to disagreements between different people!
(Just for interest – Wales in renowned for its Wild Garlic which flowers in spring and perfumes the air for miles around with garlic – there are even gastronomic food festivals, you may wish to go).

Natural selection drives the **evolution** of new species.

Key points to the process of natural selection:

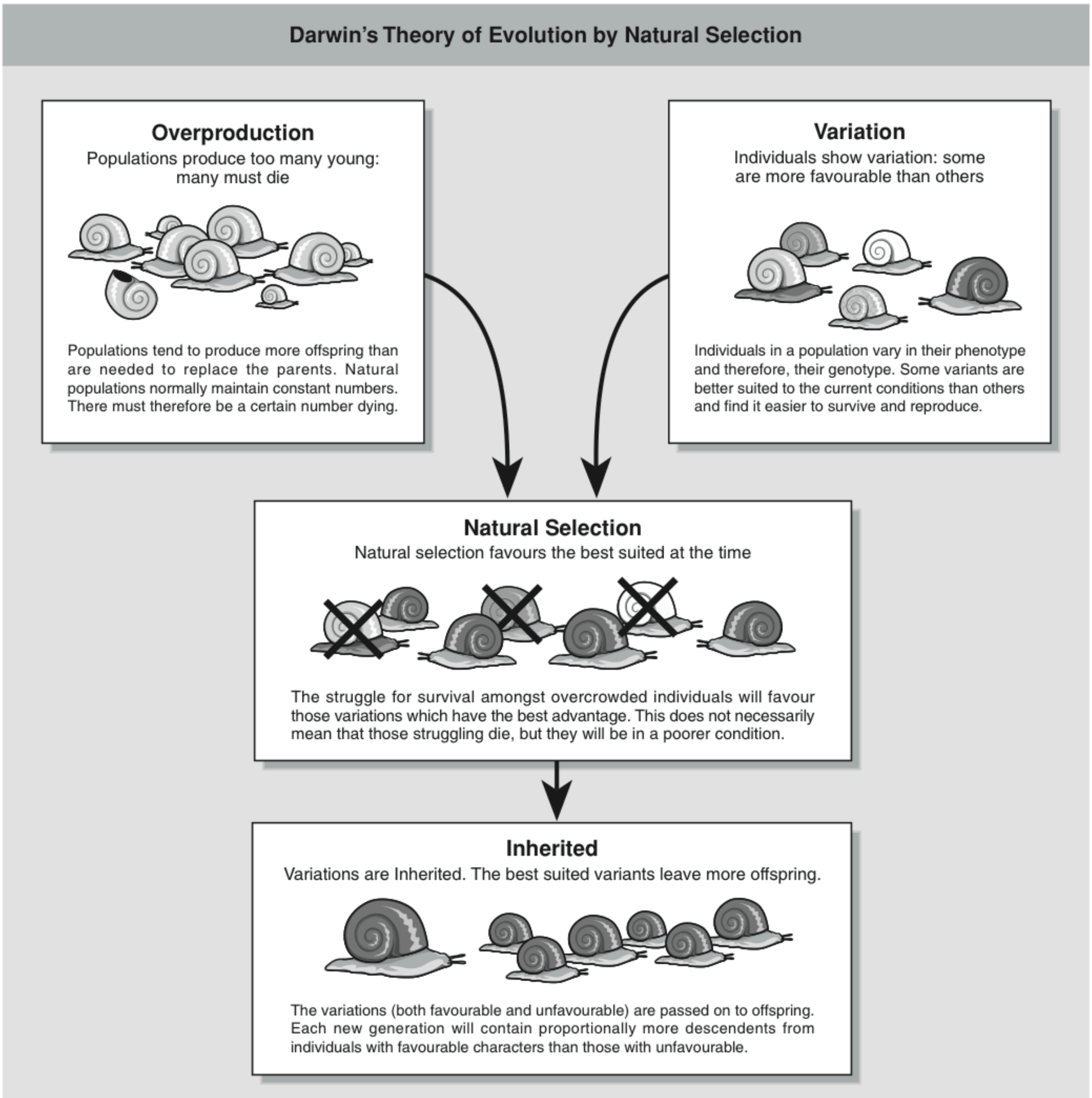
- Variation exists between organisms
- Competition for resources leading to a struggle for existence
- Best adapted (the fittest) survive (survival of the fittest)
- Fittest are able to reproduce and pass on their advantageous characteristics

The word '**evolution**' is used widely, but in Biology we specifically mean 'the process that has transformed life on Earth from its earliest beginnings to the diversity of forms we know about today. Species that have lived on Earth were and are formed by a process of continuous change – evolution. This occurs over very long periods of time referred to as geological time. Evolution is the cumulative change in the heritable characteristics of a population over time. A process of Natural Selection causes this change.

The Earth is approximately 4.6 billion years old. Modern humans have only been around for 0.0002% of that time. How do we know what early Earth really looked like and how do we know how things evolved? The evolution of complex organisms, such as humans is so gradual that no one can watch it. But evolution does leave evidence. Scientists search for clues embedded in rocks, encoded in DNA and in the shape and structure of living things.

Darwin's Theory

In 1859, Darwin and Wallace jointly proposed that new species could develop by a process of natural selection. Natural selection is the term given to the mechanism by which better adapted organisms survive to produce a greater number of viable offspring. This has the effect of increasing their proportion in the population so that they become more common. It is Darwin who is best remembered for the theory of evolution by natural selection through his famous book: '**On the origin of species by means of natural selection**', written 23 years after returning from his voyage on the Beagle, from which much of the evidence for his theory was accumulated. Although Darwin could not explain the origin of variation nor the mechanism of its transmission (this was provided later by Mendel's work), his basic theory of evolution by natural selection (outlined below) is widely accepted today. The study of population genetics has greatly improved our understanding of evolutionary processes, which are now seen largely as a (frequently gradual) change in allele frequencies within a population. Students should be aware that scientific debate on the subject of evolution centres around the relative merits of various alternative hypotheses about the nature of evolutionary processes. The debate is not about the existence of the phenomenon of evolution itself.



1. In your own words, describe how Darwin's theory of evolution by natural selection provides an explanation for the change in the appearance of a species over time:

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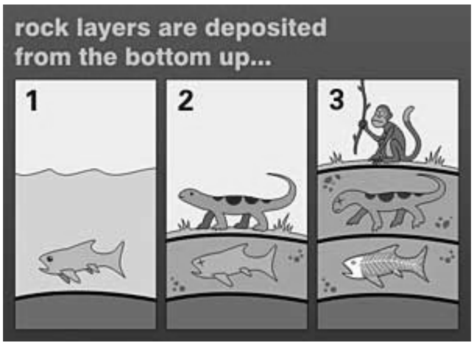
The **fossil record** shows that most species are now **extinct.**

(Background information on fossils – not specifically needed for the syllabus)

Fossils as Evidence for Evolution

Paleontologists (scientists who study fossils) believe that fossils provide the principal evidence for evolution. Fossils provide evidence of ancient life forms or ancient habitats. They can be the actual remains of a once living thing, such as bones or seeds, or even traces of past events such as dinosaur footprints.

Fossils can be found in sedimentary rocks. Sedimentary rocks are formed by sediment that is deposited over time, usually as layers at the bottom of lakes and oceans. The sediment can include minerals, small pieces of plants, dead animals and other organic matter. The layers of sedimentary rock are called strata and they can often be seen in exposed cliffs. Examples of sedimentary rocks include limestone, sandstone, mudstone and flint. Most sedimentary rock forms in horizontal layers with the youngest layers being nearest to the surface.



The study of fossils was largely developed by a French scientist called Cuvier. In examining strata near Paris, Cuvier noticed that the older the strata the more dissimilar its fossils were compared to present-day life forms. He also observed that from one layer to the next, some new species appeared whilst others disappeared.

The sequence in which layers or strata of rock have been worked out and this has led to the naming of geological eras. Paleontologists have noticed that the fossils found in the various layers were different – there appears to be a sequence of fossils.

There are dinosaur footprints in the rocks near the Severn Bridge crossing. These are the best example of Triassic dinosaur footprints in the UK! If you wish to find out more:
http://www.swga.org.uk/pdf/Bendrick.pdf

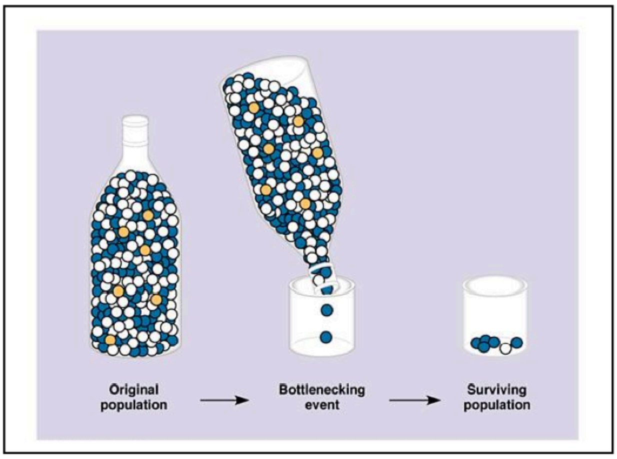
Although the fossil record is substantial and significant, it is incomplete and there are gaps in the fossil record. Give reasons why you think there are gaps in the fossil record:

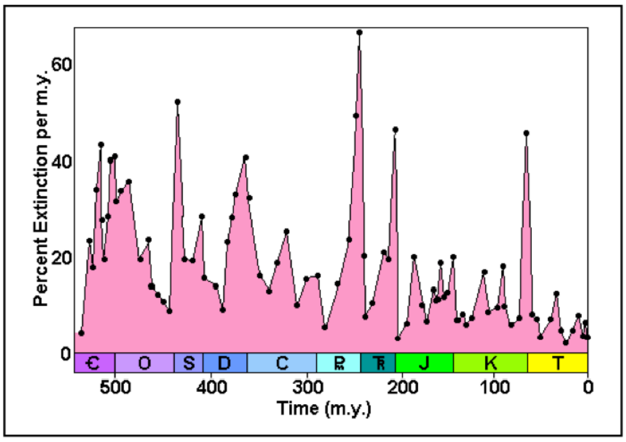
Extinction:

Extinction is a natural process largely caused by climatic, geological and biotic changes.

At present humans are the primary cause of extinction.

Evolutionary evidence has shown that biodiversity has gone through several **bottlenecks** called **mass extinctions** followed by the **radiation** of new species.





Mass extinctions are dramatic events that significantly decrease the Earth's biodiversity. These events are used to mark momentous occasions in geological time. Scientists have begun to class events according to their ecological impact on Earth, rather than by the number of species that have been lost.

Five main extinction events have been recognised, these are known as the **big 5**.

Regaining biodiversity

Large groups of related organisms are often described as arising via a process of divergent speciation called ***radiation***, in which a single ancestral form gives rise to numerous descendants or 'specialised' types. (an example is Darwin's Finches which is detailed later).

It is suggested that after a major event, such as a mass extinction, radiation starts again as the extinction has eliminated the majority of established organisms that came into being in the previous radiation.

Radiation starts with simpler, smaller and more generalised forms of an organism, such as a non-specialised finch that develops over a period of time into more specialised forms.

Always, a primitive, small, generalised type initiates the new radiation. The various forms produced by any given radiation are always more progressive than those produced by the preceding one, this is known as **adaptive radiation**.

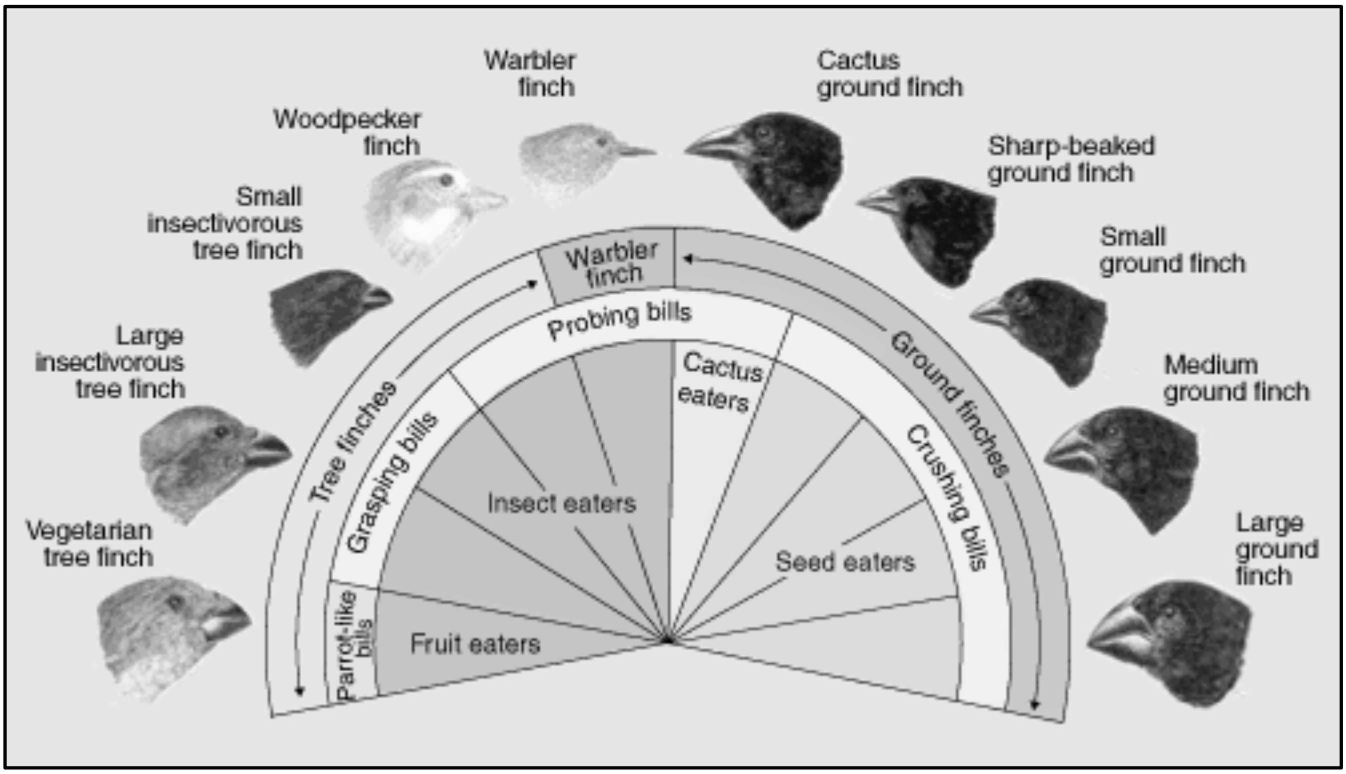
Adaptive radiation:

Darwin's finches are an example of adaptive radiation

Charles Darwin (HMS Beagle) travelled to the Galapagos Islands in 1832 and studied the variety of species. He was particularly interested in the 14 species of finches, and proposed that they all originated from one common ancestral species that must have blown off course to the islands from mainland Ecuador, as they were too small to have flown that far. With no other competition the birds populated all of the islands and over time the developed different beaks on the different islands depending on the food source there.

This process in which one species gives rise to multiple species that exploit different niches is called **adaptive radiation**. The ecological niches exert the selection pressures that push the populations in various directions. On various islands, finch species have become adapted for different diets: seeds, insects, flowers, the blood of seabirds, and leaves.

The ancestral finch was a ground-dwelling, seed-eating finch. After the burst of speciation in the Galapagos, a total of 14 species would exist: three species of ground-dwelling seed-eaters; three others living on cactuses and eating seeds; one living in trees and eating seeds; and 7 species of tree-dwelling insect-eaters.

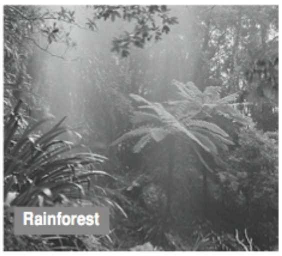


Ecosystem Stability

Ecological theory suggests that all species in an ecosystem contribute in some way to ecosystem function. Therefore, species loss past a certain point is likely to have a detrimental effect on the functioning of the ecosystem and on its ability to resist change (its stability). Although many species still await discovery, we do know that the rate of species extinction is increasing. Scientists estimate that human destruction of natural habitat is implicated in the extinction of up to 100 000 species every year. This substantial loss of biodiversity has serious implications for the long term stability of many ecosystems.

The Concept of Ecosystem Stability

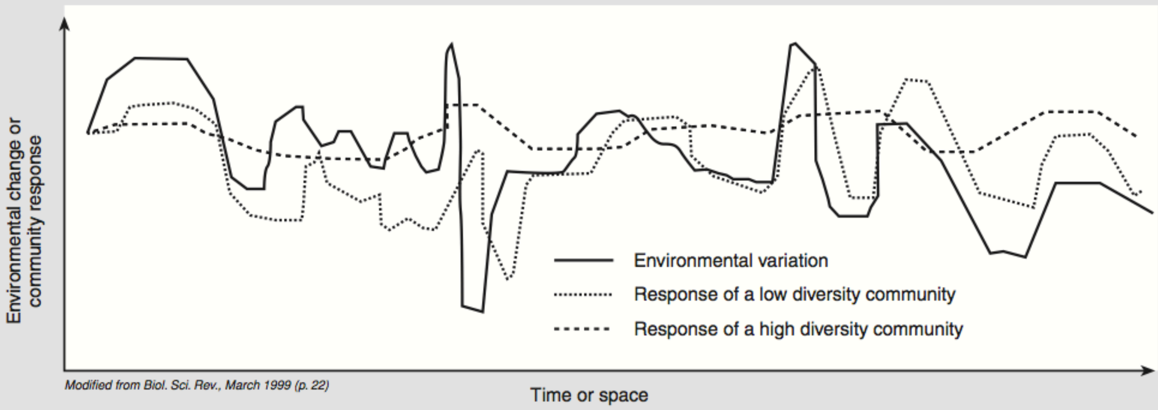
The stability of an ecosystem refers to its apparently unchanging nature over time. Ecosystem stability has various components, including **inertia** (the ability to resist disturbance) and **resilience** (ability to recover from external disturbances). Ecosystem stability is closely linked to the biodiversity of the system, although it is difficult to predict which factors will stress an ecosystem beyond its range of tolerance. It was once thought that the most stable ecosystems were those with the greatest number of species, since these systems had the greatest number of biotic interactions operating to buffer them against change. This assumption is supported by experimental evidence but there is uncertainty over what level of biodiversity provides an insurance against catastrophe.



Single species crops (monocultures), such as the soy bean crop (above, left), represent low diversity systems that can be vulnerable to disease, pests, and disturbance. In contrast, natural grasslands (above, right) may appear homogeneous, but contain many species which vary in their predominance seasonally. Although they may be easily disturbed (e.g. by burning) they are very resilient and usually recover quickly.

Tropical rainforests (above, left) represent the highest diversity systems on Earth. Whilst these ecosystems are generally resistant to disturbance, once degraded, (above, right) they have little ability to recover. The biodiversity of ecosystems at low latitudes is generally higher than that at high latitudes, where climates are harsher, niches are broader, and systems may be dependent on a small number of key species.

Community Response to Environmental Change



In models of ecosystem function, higher species diversity increases the stability of ecosystem functions such as productivity and nutrient cycling. In the graph above, note how the low diversity system varies more consistently with the environmental variation, whereas the high diversity system is buffered against major fluctuations. In any one ecosystem, some species may be more influential than others in the stability of the system. Such **keystone (key) species** have a disproportionate effect on ecosystem function due to their pivotal role in some ecosystem function such as nutrient recycling or production of plant biomass.

Elephants can change the entire vegetation structure of areas into which they migrate. Their pattern of grazing on taller plant species promotes a predominance of lower growing grasses with small leaves.

Termites are amongst the few larger soil organisms able to break down plant cellulose. They shift large quantities of soil and plant matter and have a profound effect on the rates of nutrient processing in tropical environments.

The starfish *Pisaster* is found along the coasts of North America where it feeds on mussels. If it is removed, the mussels dominate, crowding out most algae and leading to a decrease in the number of herbivore species.

Calculation and Use of Diversity Indices

One of the best ways to determine the health of an ecosystem is to measure the variety (rather than the absolute number) of organisms living in it. Certain species, called **indicator species**, are typical of ecosystems in a particular state (e.g. polluted or pristine). An objective evaluation of an ecosystem's biodiversity can provide valuable insight into its status, particularly if the species assemblages have changed as a result of disturbance.

Diversity can be quantified using a **diversity index (DI)**. Diversity indices attempt to quantify the degree of diversity and identify indicators for environmental stress or degradation. Most indices of diversity are easy to use and they are widely used in ecological work, particularly for monitoring ecosystem change or pollution. One example, which is a derivation of **Simpson's index**, is described below. Other indices produce values ranging between 0 and almost 1. These are more easily interpreted because of the more limited range of values, but no single index offers the "best" measure of diversity: they are chosen on their suitability to different situations.

Simpson's Index for finite populations

This diversity index (DI) is a commonly used inversion of Simpson's index, suitable for finite populations.

$$DI = \frac{N(N-1)}{\Sigma n(n-1)}$$

After Smith and Smith as per IOB.

Where:

- **DI** = Diversity index
- **N** = Total number of individuals (of all species) in the sample
- **n** = Number of individuals of each species in the sample

This index ranges between 1 (low diversity) and infinity. The higher the value, the greater the variety of living organisms. It can be difficult to evaluate objectively without reference to some standard ecosystem measure because the values calculated can, in theory, go to infinity.

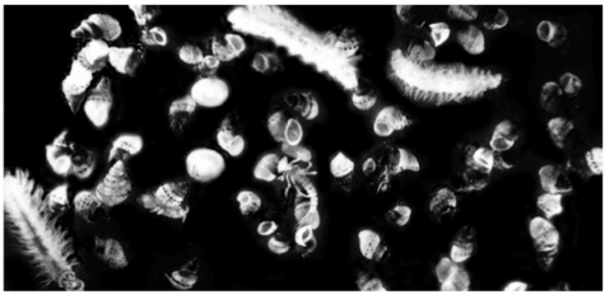
Example of species diversity in a stream

The example describes the results from a survey of stream invertebrates. The species have been identified, but this is not necessary in order to calculate diversity as long as the different species can be distinguished. Calculation of the DI using Simpson's index for finite populations is:

Species	No. of individuals
A (Common backswimmer)	12
B (Stonefly larva)	7
C (Silver water beetle)	2
D (Caddis fly larva)	6
E (Water spider)	5
Total number of individuals = 32	

$$DI = \frac{32 \times 31}{(12\times11) + (7\times6) + (2\times1) + (6\times5) + (5\times4)} = \frac{992}{226} = 4.39$$

A stream community with a high macroinvertebrate diversity (above) in contrast to a low diversity stream community (below).



Photos: Stephen Moore

1. Explain what you understand by the term **ecosystem stability**: ______________________

2. Suggest one probable reason why high biodiversity provides greater ecosystem stability: ______________________

3. Describe a situation where a species diversity index may provide useful information: ______________________

4. An area of forest floor was sampled and six invertebrate species were recorded, with counts of 7, 10, 11, 2, 4, and 3 individuals. Using Simpson's index for finite populations, calculate DI for this community:

   (a) DI= ______________________ DI = __________

   (b) Comment on the diversity of this community: ______________________

Assessing the Biodiversity of a Habitat

Species observed	Percentage cover	
	Field A	Field B
Cocksfoot grass	57	38
Timothy grass	32	16
Meadow buttercup	3	14
White clover	3	22
Creeping thistle	1	5
Dandelion	4	5
Total	100	100

Table 1 Two surveys

Key definition

Species richness is the number of species present in a habitat.

Simpson's diversity index

Simpson's diversity index is a formula used to measure the diversity of a habitat.

Species richness and evenness

When measuring **biodiversity**, we have to consider **species** richness – the number of species found in a **habitat**. The more species are present, the richer the habitat. However, richness is not sufficiently quantitative to be a measure of **diversity** on its own. It does not take into account the number of individuals in each species. For this, we need to estimate **evenness**.

Evenness is a measure of the relative numbers or **abundance** of individuals in each species. A habitat in which there are even numbers of individuals in each species is likely to be more diverse than one in which individuals of one species outnumber all the others. As discussed in spread 2.3.2, we can measure abundance in plants as percentage cover, rather than as numbers of individuals.

Table 1 shows an example of two simple surveys. Fields A and B have equal richness as they both contain six species. However, field B has greater evenness. Therefore field B would be considered more diverse.

Estimating species richness

You can use a **qualitative** survey to estimate species richness. This means that you need to make observations within the habitat and record all the different species you see. You should start by taking some samples, as described in spread 2.3.2. Your method of sampling will depend on the habitat. You should also take time to walk around the habitat and make further observations in case your samples missed some species.

Estimating species evenness

Estimating species evenness is more difficult. For this you need to carry out a **quantitative** survey.

Surveying the frequency of plants

First use the sampling techniques described in spread 2.3.2 to take your samples. Then count the number of plants of each species per unit area, or measure the percentage cover of each species. With large plants it is better to count the number of individuals per unit area. With smaller plants, such as grasses and herbs, it is better to measure the percentage cover. You can use similar techniques in both terrestrial and aquatic habitats. You may need to take extra precautions when sampling aquatic habitats!

Measuring the density of animals in a habitat

Measuring the density of animals in a habitat means calculating how many animals of each species there are per unit area of the habitat.

- For larger animals, such as badgers or deer, you will need to observe carefully and count the individuals present. However, this is not possible for most animals, as they are too small.
- For smaller animals, you will need to take samples of the animals present. As mentioned in spread 2.3.3, sampling animals involves trapping them. But you cannot be certain you have trapped all the animals in the population. You can calculate population size using the mark-and-recapture technique.

- First you need to capture a sample of animals, then mark each individual in some way that causes it no harm. The number captured will be C_1. Then release them and leave the traps for another period of time. The number captured on this second occasion will be C_2. The number of already marked animals captured on the second occasion is C_3.
- Then you can calculate the total population using the formula:

  total population = $(C_1 \times C_2)/C_3$

- Mark-and-recapture will not work for the numerous tiny animals living in soil. Here the only way to estimate population size is to take a sample of soil and sift through it to find all the individuals and count them.
- Sampling in water is a similar process. You can use a net to sample in the body of the water and to sift through the mud at the bottom. Then you can estimate population size and density.

Simpson's diversity index

Simpson's diversity index is a measure of the diversity of a habitat. It takes into account both species richness and species evenness. It is calculated by the formula:

$$D = 1 - [\Sigma(n/N)^2]$$

where n is the number of individuals of a particular species (or the percentage cover for plants) and N is the total number of all individuals of all species (or the percentage cover for plants).

Table 2 shows how to apply Simpson's diversity index to the results for fields A and B above.

	Field A			Field B		
	n	n/N	$(n/N)^2$	n	n/N	$(n/N)^2$
Cocksfoot grass	57	0.57	0.3249	38	0.38	0.1444
Timothy grass	32	0.32	0.1024	16	0.16	0.0256
Meadow buttercup	3	0.03	0.0009	14	0.14	0.0196
White clover	3	0.03	0.0009	22	0.22	0.0484
Creeping thistle	1	0.01	0.0001	5	0.05	0.0025
Dandelion	4	0.04	0.0016	5	0.05	0.0025
Sum (Σ)	–	–	0.4308	–	–	0.243
1 – Σ	–	–	0.5692	–	–	0.757

Table 2 Simpson's diversity index

Using Simpson's diversity index

A high value of Simpson's index indicates a diverse habitat. Such a habitat provides a place for many different species and many organisms to live. A small change to the environment may affect one species. If this species is only a small part of the habitat, the total number of individuals affected is a small proportion of the total number present. Therefore the effect on the whole habitat is small. The habitat tends to be stable and able to withstand change.

A low value for diversity suggests a habitat dominated by a few species. In this case, a small change to the environment that affects one of those species could damage or destroy the whole habitat. Such a small change could be a disease or predator, or even something that humans have done nearby.

Questions

1 Explain the difference between species richness and species evenness.

2 Suggest what precautions you may need to take when measuring populations of aquatic animals or plants.

3 Explain why a habitat with high diversity tends to be more stable than one with low diversity.

Assessing the Biodiversity within a Single Species

To measure the genetic diversity of a particular gene, scientists look at how many different versions of it (called alleles) are present in a population. For example, one gene may determine the flower color of a plant. Different alleles may exist for that gene (e.g., a pink allele, a purple allele, and a white allele). In each case, the same gene determines flower color—but the exact order of DNA letters that make up the gene are different for each allele. When all or nearly all members of a population have the same allele, that population is said to have low genetic diversity at that gene. But when many different versions of the gene exist in a population, the population has high genetic diversity at that gene.

Why is genetic diversity important?

Populations or species with low genetic diversity at many genes are at risk. When diversity is very low, all the individuals are nearly identical. If a new environmental pressure, such as a disease, comes along, all of the individuals within the population may get the disease and die. But in a population with high genetic diversity, chances are better that some individuals will have a genetic makeup that allows them to survive. These individuals will reproduce, and the population will survive.

The genetic diversity of a species is always changing. No matter how many variants of a gene are present in a population today, only the variants that survive in the next generation can contribute to species diversity in the future. Once gene variants are lost, they cannot be recovered.